SIMPLEV - A SIMPLE ELECTRIC VEHICLE SIMULATION PROGRAM

Version 2.0

INTRODUCTION

The simple electric vehicle (SIMPLEV) simulation code originated with the work performed while developing the Simplified Federal Urban Driving Schedule (SFUDS) battery test cycle in conjunction with the Department of Energy (DOE) Battery Test Working Task Force. Originally two simulations for the Improved Dual Shaft Electric Propulsion (IDSEP) vehicle were written. One simulation, called PTOV, determined the velocity of the IDSEP vehicle for a given power input to the driveline. The other program, called VTOP, determined the battery power required to propel the IDSEP vehicle over a given velocity profile. The vehicle powertrain in these programs was described by a single efficiency versus motor torque and speed matrix. After the work on the SFUDS was completed, the need for a more detailed PC based electric vehicle simulation tool developed. These programs were modified, improved, and combined into the original SIMPLEV code. Various other refinements were made to this code as time progressed. The result of this effort was the previously released SIMPLEV Version 1.0, documented in SIMPLEV: A Simple Electric Vehicle Simulation Program - Version 1.0 (DOE 1991).

Since the release of Version 1.0, users of the code have made suggestions to improve SIMPLEV's utility. Many of these suggestions were subsequently incorporated into Version 2.0. The following upgrades have been made and conveniences added.

Errors Corrected

Several minor anomalies have been identified by users of the Version 1.0 software. The most significant errors occurred in the conversion from English units to SI units, are quite obvious to the user, and did not affect most of the calculated results.

Function and Control Keys

Function and control key assignments have been expanded in SIMPLEV Version 2.0. The uses of the function keys and control+letter key combinations are as follows:

<F2> displays the battery power, battery voltage, and battery current graphs regardless of which screen was previously being viewed. The graphs are automatically redrawn starting at the beginning of the present cycle.

<F3> displays the speed, motor power, and driveline component efficiencies graphs regardless of which screen was previously being viewed. The graphs are automatically redrawn starting at the beginning of the present cycle.

<F4> displays a screen of calculated point-by-point results in numerical format regardless of which screen was previously being viewed.

Note: The user may switch between the three display modes while SIMPLEV is executing.

<F5> sets the Auxiliary Power Unit (APU) in manual mode and toggles the APU on and off. This key is only active if an APU is chosen as part of the simulation.

<F6> sets the APU in automatic mode, which has the effect of cancelling the manual mode.

<Ctrl+i> prints an intermediate summary of the results of the simulation up to the point that the key combination was pressed.

The effect of the other function keys (i.e. <F1>, <F7>, <F8>, <F9>, and <F10>) remain the same as in Version 1.0 .

Wheel Slip/Skid

Version 1.0 assumed that there was always sufficient traction between the road surface and the vehicle wheels to prevent wheel skidding. Vehicle acceleration was only limited by the motor torque, inverter current, or battery voltage. Vehicle deceleration had no limitations. A feature has been added in Version 2.0

which limits the vehicle acceleration and deceleration to maximum that the wheel traction can allow. (Note: acceleration still may be limited by other components).

Maximum Motor Torque During Regenerative Braking

The maximum motor torque during regenerative braking (thus power delivered back to the battery) was not controlled in Version 1.0. Version 2.0 limits the allowable regeneration by the maximum motor torque while operating in this quadrant.

Auxiliary Power Unit

Estimates on the performance of an APU have been added in SIMPLEV Version 2.0. Three separate components (engine, generator, and catalytic converter) of an APU are modeled, allowing estimates of fuel consumption, and carbon dioxide, hydrocarbon, and oxides of nitrogen emissions. Two methods of controlling the APU output power are available; a specified constant power output and power output based upon a user input multiple of the average traction power (averaged over a specified time period) with limitations on the maximum and minimum power. Automatic operation (based upon battery depth-of-discharge) and manual operation ("on" and "off" toggled by the <F5> key) are incorporated into Version 2.0.

User-written Files

Component information files which are written by the user are more easily selected with Version 2.0. A list of files having the proper filename extension are displayed on the screen. The files can be selected by simply pressing the letter associated with the desired file.

Calculated Results

With Version 2.0, the user can select parameters that he wishes written to a file, instead of the predetermined parameter lists of Version 1.0. A total of 41 parameters are available (21 if an APU is not simulated).

Output Devices

One of six output devices may be selected by the user as well as to none. These seven device names are as follows: LPT1, LPT2, COM1, CON (screen), AUX, NUL, and a user named DOS ASCII file. Other devices may also be specified by the user.

Time Axis

The horizontal axis (time) on the screen graphs is automatically labeled to show the total simulated time on succeeding screens.

Execution Delay

The execution of the program may be slowed by the user (as in Version 1.0), however, the execution speed of Version 2.0 is based upon real time and not dependent upon the user's computer speed. One-third, two-thirds, and one-second delays for each calculated point are available.

GENERAL DESCRIPTION

SIMPLEV 2.0 is a menu driven, general purpose simulation program intended for use as a tool for performing parametric studies of electric and/or series hybrid (i.e. systems employing batteries and heat engine driven generators as their mobile energy source) vehicles. The source code of the compiled program program is written in BASIC and will run on any IBM DOS compatible personal computer (PC). The program is run interactively and guides the user through all of the necessary input steps. It is easily run by users whose background contains only an elementary knowledge of computer simulation programs. All parameters are input by the user either from the menus or as ASCII data files. To start the program, type SIMPLEV from the directory where SIMPLEV resides and it will prompt you through various choices of vehicles, driveline components, batteries, driving cycles, and road conditions (grade, wind speed and direction), etc. The menu selected propulsion system components may be scaled larger or smaller by the user, if desired. Choices of graphical display outputs and capturing of point-by-point calculated results are also made by the user.

Simulation Methodology

The methodology used in this simulation is straightforward. SIMPLEV first determines the power required to propel the vehicle from the speed at one point in time to the next from the road load calculated from user inputs. The power at each component interface is then determined from a linear interpolation (single or double, as required) of the efficiency from component matrices, which results in the electrical power required to drive the vehicle. Electrical power from an auxiliary power unit (if chosen) is then calculated and algebraically added to the electrical power required for traction and accessories. This net power from the battery is then converted into voltage and current using the open circuit voltage and resistance characteristics of the battery. If an operating limit of some component (wheel traction, maximum motor torque, maximum controller/inverter current or minimum voltage) is encountered such that the target speed is unattainable, SIMPLEV then iterates a solution that produces the closest speed possible while still satisfying the operating limitations of all components. Thus under these conditions, the "best effort" attempt of the driving cycle is simulated.

Program Termination

While executing a driving cycle SIMPLEV continues to "drive" until one of the following conditions are met:

1. the run is terminated by the user (<F9> or <F10> key)
2. the maximum number of cycles or approximate distance input by the user have been completed
3. the battery capacity is depleted (i.e. 100% depth-of-discharge) and all APU fuel is consumed
4. the vehicle fails to meet the minimum required speed of the FUDS driving cycle.

The notation, < >, refers to the non-alphanumeric keys on the PC keyboard. During the input session of SIMPLEV, numbered responses to menu selections and yes/no questions are not followed by <Enter> while numeric or string inputs must be followed by <Enter>.

Referring to Item 4. above, the minimum speed condition is defined (on the Federal Urban Driving Cycle only) as the inability of the vehicle to remain within $\pm$3.2 km/h (2 mph) within $\pm$1 second of the desired speed. The exception to this is during the 187 - 305 second portion of the FUDS cycle, where the limits are as defined as in the draft SAE J227 EV Test Procedure.

Maximum effort accelerations are automatically terminated after 120 seconds (data points) are calculated without regard to vehicle speed.

Upon normal program completion, the driving cycle is stopped and various quantities are calculated and sent to the specified device. Any requested point-by-point results are saved in an ASCII text file as the program executes. Prematurely terminating the program with the <F9> key immediately ends the program execution and returns the system to the DOS command level.

Report Organization

This manual is written in two main technical sections. The section entitled "Using SIMPLEV" is written to guide the user through the menus of the program with an explanation of the selected options. The user with only an elementary knowledge of computer programs and engineering principles will be able to

effectively use SIMPLEV after mastering this section. The second section (entitled "PROGRAM DESCRIPTION") is a detailed explanation of the mathematical methodology, equations used and the ASCII input data files. This section is written for the user desiring to define his own vehicles and components, and to understand SIMPLEV's underlying principles and assumptions.

Executing SIMPLEV

SIMPLEV Computer Files

The files listed in Table 1 are furnished with SIMPLEV Version 2.0. These files consist of the executable simulation code (SIMPLEV.EXE) and a variety of files containing vehicle and powertrain component descriptions. The component data files used by SIMPLEV are selectable from the program menus. The data contained in these files were either obtained from detailed component dynamometer or battery test data, inferred from vehicle test data, converted from the ELVEC bulk data file, or in some cases, are an engineering judgement of the behavior characteristics of the component. Many of these data files have been extensively used and are believed to represent the named vehicle and component behavior reasonably accurately, however, the user is cautioned to verify for himself the validity of the component descriptions prior to drawing any conclusions based upon simulations using this data. The user is free to modify any of these data files or construct his own data files using any software which can edit or produce ASCII files.

Table 1. List of files supplied with SIMPLEV Version 3.1

APU1.BLK
APU2.BLK
COASTDWN.BLK
CONST-SP.BLK.
CVT-CVT.BLK
DSEP.BLK
ETV-1.BLK
ETX-I.BLK
ETX-II.BLK
IDSEP.BLK
MEV-75.BLK
PAR-HYB.BLK.
ULTRA1.BLK
ULTRA2.BLK
ULTRA3.BLK
3ET-205.BTY
6ETX-100.BTY
6V180.BTY
ALCO2200.BTY.
B-11-1.BTY
B-11-2.BTY
CSPL.BTY.
ED150P.BTY
EV5T.BTY
HIVOLT.BTY
NIF170.BTY
SAMPLE2.CAT
SAMPLE3.CAT
SAMPLE.CAT
20MPH.CYC.
2FUDS2HI.CYC
2HI2FUDSCYC
2HIFUDS.CYC
30MPH.CYC.
35MPH.CYC.
40MPH.CYC.
45MPH.CYC.
55MPH.CYC.
60MPH.CYC.
ACCEL.CYC.
A-CYCLE.CYC
B-CYCLE.CYC
C-CYCLE.CYC
CONST-SP.CYC
D-CYCLE.CYC
FUDS.CYC
FUDSWAY.CYC
HIFUDS.CYC.
HIWAY.CYC.
SFUDS79.CYC.
TEST.CYD
INSTALL.DOC
SAMPLE.ENG
SAMPLE2.ENG
COASTDWN.EXE
BLKEDIT.EXE.
INSTALL.EXE.
SIMPLEV.EXE.
SAMPLE.GEN.
SAMPLE2.GEN
SAMPLE3.GEN
TESTGRD.GRD
1-PCT.GRD
1-PCTDN.GRD
1-PCTUP.GRD.
1-SQUARE.GRD
1-SQWGR.GRD
2-PCTDN.GRD.
2-PCTUP.GRD.
OVAL8.GRD.
OVAL8WG.GRD
TESTCST.GRD.
ZERO.GRD
ACCESSLD.HLP
AIR.HLP
APU.HLP
BATTERY.HLP
BLKEDIT.HLP
CATCONVHLP
CHGINPS.HLP
COAST.HLP
CONTROLSHLP
CYCLE.HLP
DEVICE.HLP
DRVLINES.HLP
ENGINE.HLP
GENER.HLP
GRADE.HLP
GRAPH.HLP
INITIAL.HLP
INVERTERHLP
KEYS.HLP
MOTOR.HLP
SAVEBLKHLP
SAVEDAT.HLP
SCREENSHLP
TRANS.HLP
ULTRA.HLP
ULTRA1.HLP
ULTRA2.HLP
ULTRA3.HLP
ULTRINIT.HLP
VEHICLE.HLP
WIND.HLP
CITY-1.HSC
CITY-2.HSC
CITY-3.HSC
HIWAY-1.HSC
BATTERY.INF
BULK.INF
CATCONV.INF
CONTROLS.INF
CYCLE.INF
ENGINE.INF
GENER.INF
GRADE.INF
INVERTER.INF
MOTOR.INF
TRANS.INF
UPDATE.INF
UTRAT1.INF
VEHICLE.INF
WIND.INF
ETV-1.INV
ETX-I.INV
ETX-II.INV
IDSEP.INV
MEV-100.INV
MEV-50.INV
MEV-75.INV
TB-1.INV
ETV-1.MOT
ETX-I.MOT
ETX-II.MOT
IDSEP.MOT
MEV-100.MOT
MEV-50.MOT
MEV-75.MOT
TB-1.MOT
CVT.TX
ETV-1.TX
ETX-I.TX
ETX-II.TX
IDSEP.TX
MEV-75.TX
TB-1.TX
BEDVAN.VEH
DSEP.VEH
ETV-1.VEH
ETX-I.VEH
ETX-II.VEH
EVCORT.VEH
G-VAN.VEH
IDSEP.VEH
IMPACT.VEH
MEV-75.VEH
SATURN.VEH
SOLQVAN.VEH
TB-1.VEH
TEVAN.VEH
N5-10.WND
NNW-GUST.WND
ZERO.WND

Hardware Requirements

SIMPLEV requires approximately 280 kB of RAM memory to load and run. Approximately 420 KB of disk storage is required to store the executable code (SIMPLEV.EXE) and the input data files listed in Table 1. Additional disk storage is required if the user wishes write his own component files or save the calculated results to ASCII format files. The amount of disk space required for these files varies, however, files containing calculated results can become very large.

SIMPLEV may be executed from either a hard, floppy, or virtual disk drive on any IBM DOS compatible PC. The printer control codes used by SIMPLEV are minimal, and are generally compatible with IBM and Epson printers, but may produce erratic results on other printers. If the user anticipates wanting a hardcopy of the graphical displays, the printer must have the ability of printing graphics characters. The graphical displays will be sent to the same device that the "Print Screen" key accesses. Due to disk file I/O operations, the input session during SIMPLEV execution will run generally faster from a hard or virtual disk drive. If SIMPLEV's output is to be written to a file, the execution speed will also be affected by the speed of the disk I/O.

Starting SIMPLEV

To start the program, type SIMPLEV <Enter> from the DOS command environment in the drive and directory in which SIMPLEV.EXE resides. Any of the menu selectable data files which are anticipated to be used (i.e. files with ".VEH". ".MOT", ".INV", ".TX", ".CYC", ".BTY", ".CAT", ".ENG", and ".GEN" extensions) must also reside in this drive and directory. The DOS GRAPHICS command generally must be executed prior to running SIMPLEV if the user wishes to print hardcopies of the graphs. The DOS GRAPHICS command need only be executed once each time the PC is booted.

It is suggested that in order to become familiar with executing SIMPLEV, the new user run the simulation while simultaneously reading the remainder of this section.

Input Screen

Introduction Screen. After executing the program (i.e. typing SIMPLEV <Enter>) an introduction screen will be displayed (Figure 1).

Function/Control + Letter Keys--The introduction screen shows the uses of some of the function keys. Depending upon the simulation options chosen, some of these function keys may be inactive. The uses of the function keys are as follows:

> <F1> shells SIMPLEV to the DOS command level during the simulation. To return to the simulation, type "EXIT"<Enter> from the DOS command level. In most cases the information on the screen when <F1> is pressed will not be redisplayed upon returning to the simulation, however, <F2>, <F3>, or <F4> will restore the screen as indicated below.
>
> <F2> displays the battery power, battery voltage, and battery current graphs regardless of which screen was previously viewed. The graphs are automatically redrawn starting at the beginning of the present cycle.
>
> <F3> displays the speed, motor power, and driveline component efficiencies graphs regardless of which screen was previously viewed. The graphs are automatically redrawn starting at the beginning of the present cycle.

<F4> displays a screen of calculated point-by-point results in numerical format regardless of which screen was previously viewed.

Note: The user may switch between the three display modes while SIMPLEV is executing.

<F5> sets the Auxiliary Power Unit (APU) in manual mode and toggles the APU on and off. This key is only active if an APU is chosen as part of the simulation.

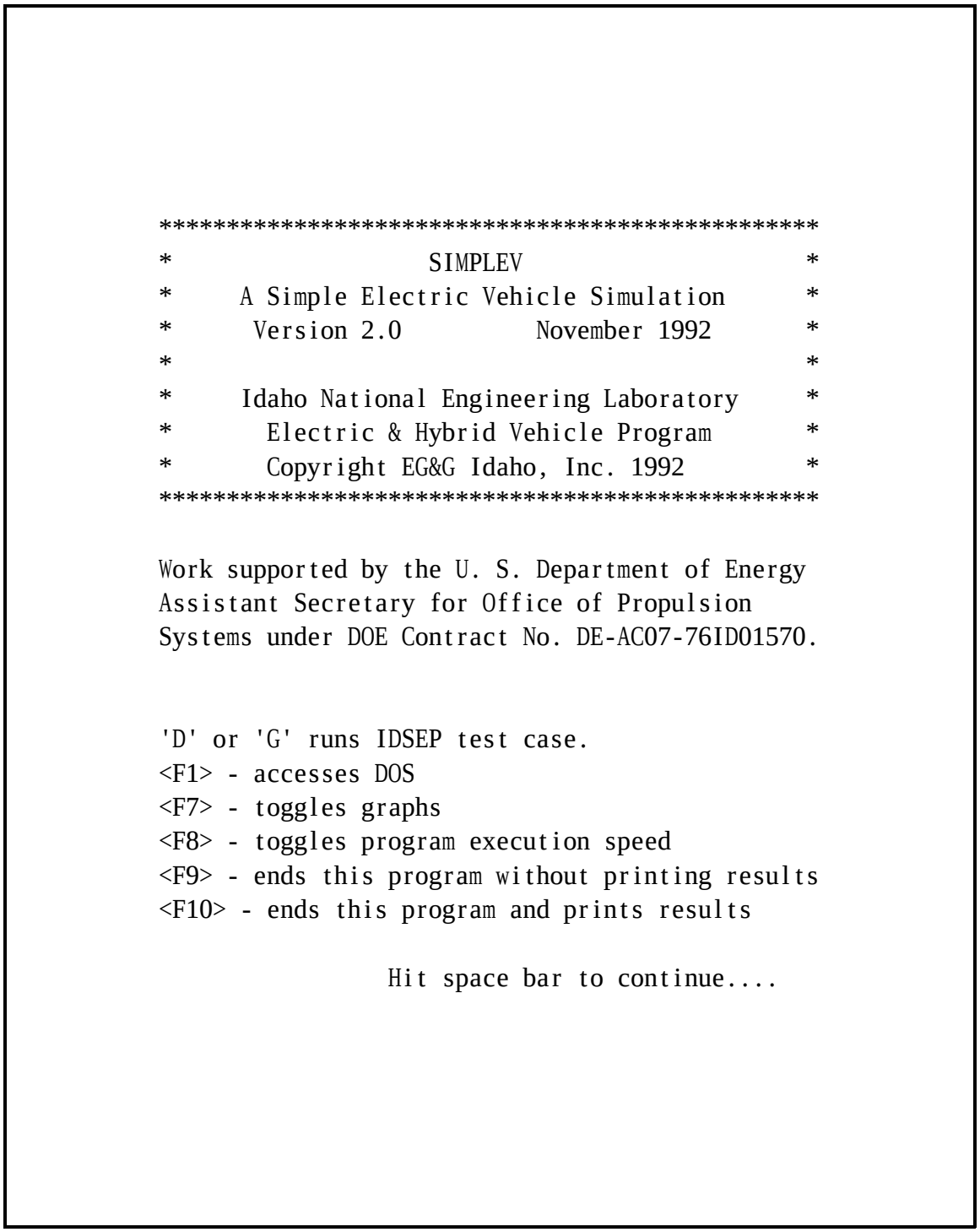

Figure 1. SIMPLEV introduction screen displayed after executing SIMPLEV.EXE

<F6> sets the APU in automatic mode, which has the effect of cancelling the manual mode. This key is only active if an APU is chosen as part of the simulation, and the automatic mode of operation was selected.

<F7> toggles the printing of the display's graphics. This key is active only if the user chooses to print graphs during the input session.

<F8> toggles between 4 execution speeds during the simulation. This function is useful to slow the program execution when it is too rapid to effectively observe the results. One-third, two-thirds and one-second delays at each calculated point are possible.

<F9> immediately ends program execution and returns the user to the DOS command level.

<F10> immediately ends program execution, calculates results up to the point that the key was pressed, produces output as selected during the input session, and returns to the DOS command level.

<Ctrl+i> prints an intermediate summary of the results of the simulation up to the point that the key combination was pressed, and then continues execution.

Sample Simulations--A selected test case may be run at the introduction screen. This feature is useful to ascertain if SIMPLEV runs properly. Entering a "D" will cause the remainder of the inputs to be bypassed and the program will run using preselected inputs. This output may then be compared to the output in Appendix A to assure the user that SIMPLEV is working properly on his equipment. Entering a "G" will run the same test case and print a sample graph on the selected parallel printer.

To continue with the simulation and begin the input session, the user should enter <SPACE> (space bar) as indicated on the screen.

Vehicle Menu. After entering <SPACE> at the introduction display, the vehicle menu (Figure 2) is displayed. The user should then select one of the options listed. For alpha characters, either upper or lower case characters may be used. If an input not on the menu is chosen, the PC will beep and the user must select a valid choice.

If the simulation of a vehicle which is not on the menu (i.e. a user written vehicle data file) is desired, the user should enter "U". He will then shown a list of files from the current directory having the ".VEH" extension. Several screens of files can be listed. Figure 3 shows this list for the files supplied with Version 2.0. If more than 26 files are found, the user may scroll through the list by pressing <SPACE>. Pressing "0" (zero) redisplays the list from the beginning. To choose a file, press the letter associated with the desired file (either upper or lower case). In order for this option to work, the DOS directory command ("dir") must lie within the DOS path specification.

Another option available at this time is to access the DOS command level by entering "S". This feature is useful for interrupting SIMPLEV to perform other computer functions, [such as changing the default path (drive/directory) that is searched for input files]. To change the default path, select "S" from any input menu, enter "CD [d:]\path <Enter>" at the DOS prompt, and then type "EXIT <Enter>" to return to SIMPLEV. Because SIMPLEV will remain in memory, only a limited amount of the computer's memory remains for running other programs.

Motor Menu. After selecting a valid menu choice the vehicle data file is read and the motor selection menu appears on the display as shown in Figure 4. The user should then select one of the options listed. For alpha characters, either upper or lower case characters may be used. If an input not on the menu is chosen, the PC will beep and the user may then select again. The other method of selecting a motor (".MOT" extension) file or accessing DOS are also available as described above under Vehicle Menu.

Inverter/Controller Menu. After selecting a valid menu choice for motor data file, the inverter/controller selection menu appears on the display as shown in Figure 5. The user should then select one of the options listed. For alpha characters, either upper or lower case characters may be used. If an input not on the menu is chosen, the PC will beep and the user may then

Figure 2 & 3

Figure 4 & 5

select again. The other method of selecting an inverter/controller (".INV") file or accessing DOS are also available as described above under Vehicle Menu.

After selecting the inverter/controller, the user is given the opportunity to scale the selected motor and/or inverter/controller (see Figure 6). The details of the scaling methodology are discussed under the Program Description section. If the user chooses to scale either or both of these components, he should enter "Y" at the appropriate prompt and the user will be asked to supply the appropriate information via the keyboard. Once the appropriate information is entered, the motor data file and the inverter/controller data files are read, the data is scaled, and the user is given the opportunity to adjust the operating limits of the selected inverter/controller as shown in Figure 7. If the user wishes to change either or both the minimum voltage and maximum current, he should answer "Y" to the appropriate question. The desired operating limits for the inverter/controller may then entered via the keyboard at the appropriate prompts. The transmission selection menu then follows.

Transmission Menu. The transmission selection menu is shown in Figure 8. The user should select one of the options listed. For alpha characters, either upper or lower case characters may be used. If an input not on the menu is chosen, the PC will beep and the user may then select again. The other method of selecting a transmission (".TX") file or accessing DOS are also available as described above under Vehicle Menu.

Choosing and Scaling Transmission Data--After a valid transmission choice is entered (other than a CVT), the user is then prompted if he wants to scale the selected transmission. The details of the scaling methodology are discussed in the Program Description section. If the user chooses to scale the transmission (Figure 9), he should enter "Y" at the appropriate prompt and the user will be asked to supply the appropriate information via the keyboard. Once the appropriate information is entered, the transmission data file is read and scaled, if necessary, and the driving cycle selection menu is displayed.

Continuously Variable Transmissions--An additional available transmission option is a simple representation of a continuously variable transmission (CVT). If this option is

Figures 6 and 7

Figure 8 and 9

chosen, information is prompted for as shown in Figure 10. The meaning of these parameters and how they are used in SIMPLEV are discussed in the Program Description section.

Driving Cycle Menu. The driving cycle selection menu is shown in Figure 11. The user should select one of the options listed. For alpha characters, either upper or lower case characters may be used. If an input not on the menu is chosen, the PC will beep and the user may then select again. The other method of selecting a driving schedule (".CYC") file or accessing DOS are also available as described above under Vehicle Menu. The standard driving cycles (i. e. FUDS, SAE J227a "A", "B", "C" and "D") listed in the driving cycle data files were obtained from the final draft SAE J227 Electric Vehicle Test Procedure dated 05/08/86.

After the selection of a valid driving cycle, the user is then prompted for a maximum number of cycles (or approximate maximum distance for the constant speed choices). If a maximum number of driving cycles (or maximum distance) chosen is not within the driving range of the vehicle, SIMPLEV automatically terminates the simulation when the battery is depleted.

Federal Urban Driving Cycle Termination--Because the measured range of an electric vehicle on the FUDS driving cycle is dependent upon the point at which the test is terminated, it is important that the user understand the methodology employed within SIMPLEV relating to vehicle performance on this cycle and, in some cases, the point at which the simulation is stopped and range calculated.

The selected vehicle and component configuration is simulated on the cycle in a "best effort" fashion. Generally, the minimum vehicle performance on the Federal Urban Driving Schedule is defined as the vehicle's inability to attain a speed of $\pm$ 2 mph within $\pm$1 second of the target speed. However, SIMPLEV simulates the Federal Urban Driving Schedule according to the test procedure description given by the Final Draft SAE J227 Electric Vehicle Test Procedure dated 5/8/86 as follows. The point at which the vehicle cannot meet the $\pm$ 2 mph speed within $\pm$ 1 second of the target speed either terminates the cycle or is marked on the graphical display by a vertical line, depending upon where in the test cycle this occurs. As a reminder, the word "FLAG" appears on the display to show that this has occurred. In accord with the draft SAE procedure, if this occurs between 164 and 305 seconds of the cycle, the vehicle is

Figure 10 and 11

allowed to continue until either the $\pm$ 2 mph speed within $\pm$ 1 second cannot be met during any other portion of the cycle or the vehicle's best effort cannot attain 72 km/h within 30 s after 187 seconds and hold that speed until the 305 second mark of the cycle.

These performance limits can be bypassed by renaming the file names "FUDS.CYC" (keeping the .CYC extension) and then selecting this file with the "U" option from the Transmission Selection Menu.

Road Conditions--A series of prompts requesting information regarding road conditions (see Figure 12) will be displayed next. Pressing <Enter> to any of these prompts results in the built in default values being used. These default values are as follows:

Percent grade = 0%
Vehicle direction = 0°
Wind speed = 0 mph
Wind Direction = 0°
Air density = .002266 slug/ft^3
Aerodynamic drag coefficient wind correction factors:
a = .00194
b = 1.657026

If a non-zero value for either wind speed or wind direction is chosen, values for calculating the vehicle aerodynamic drag coefficient, C_d, are requested. These factors for modifying the vehicle aerodynamic drag coefficient are explained in detail in the Program Description section.

Battery Menu. The battery selection menu is shown in Figure 13. The user should select one of the options listed. For alpha characters, either upper or lower case characters may be used. If an input not on the menu is chosen, the PC will beep and the user may then select again. The other method of selecting a battery (".BTY") file or accessing DOS are also available as described above under Vehicle Menu. The format of the battery data files is contained in the Program Description section enabling the user to define his own batteries.

Figure 12 and 13

After the selection of a valid battery choice, a several battery-related options are available to the user (see Figure 14): battery scaling, initial ampere-hours removed and number of modules in series desired. Specifying the number of modules is not an option with the sodium sulfur batteries chosen from the menu. If the calculated open circuit voltage for the number of modules is below the minimum inverter voltage, a message is displayed informing the user of this fact, and the user is prompted to re-enter the number of modules. The battery scaling methodology is described in detail in the Program Description section.

Auxiliary Power Unit. The user is then prompted as to whether or not to include an APU. If the user wishes to include an APU, he should enter "Y" in response to the prompt. He will then be prompted for files containing information on the engine, generator, and catalytic converter. If the user chooses not to include an APU (by entering "N"), then the next input required is a value for the auxiliary electrical load (see below).

The auxiliary power unit (series hybrid) supplies electrical power at the battery terminals, which may be used for either vehicle propulsion, auxiliary loads, battery charging, or a combination of these uses. If an APU option is chosen, the user is prompted to input the necessary information.

Engine File Selection--A list of engine information files (i.e. those having the ".ENG" filename extension will be displayed which reside in the default path. Enter the letter associated with the desired engine file.

Catalytic Converter File Selection--A list of catalytic converter information files (i.e. those having the ".CAT" filename extension will next be displayed which reside in the default path. Enter the letter associated with the desired engine file.

Generator File Selection--A list of generator information files (i.e. those having the ".GEN" filename extension will next be displayed which reside in the default path. Enter the letter associated with the desired engine file.

Figure 14

Other APU Information To Be Input--After the user's selection of APU component information files are read by SIMPLEV, additional information must be entered via the computer keyboard. Referring to Figure 15, the user must select from one of two options regarding the APU power output. Selection "1 - Constant generator output" provides for a user specified generator output. If this is selected, then a value (in watts) must be input at the prompt. If selection "2 - Variable generator output" is chosen, the generator output will be based upon the battery power used for traction averaged over a specified time period. This averaged traction power will be multiplied by the value entered.

SIMPLEV will then prompt the user for the particular mode of APU operation desired. If the automatic mode is chosen, the APU will operate between the specified battery DOD range input by the user. If "manual only" mode is chosen, the user must turn the APU "on" and/or "off" using the <F5> key during program execution. Choosing the automatic mode of operation does not preclude the user from manually operating the APU. In any case, the APU will automatically be turned "off" if the battery reaches 0% DOD (or 100% State-of-charge).

For investigative purposes, the option of artificially fixing the battery capacity when the APU is initially turned on is provided. This option has been found useful in studies where it was desired for the APU to return a fixed amount of ampere-hours to the battery.

The maximum generator and engine power, and the minimum generator power read from the APU component files are then displayed and the user is given an opportunity to change them if desired. The user can either modify each of these values, or enter <Enter> (see Figure 16) to retain the values given. SIMPLEV will caution the user if a generator power in excess of the engine power multiplied by the maximum generator efficiency is specified. In this event, the user may re-specify the maximum generator and engine power values.

For the catalytic converter, the option of always operating the converter at maximum efficiency (as if it were preheated) is offered. Enter "Y" a the appropriate prompt if this condition is desired, otherwise enter "N" and the catalytic converter efficiency will be governed by the equations described in the following section of this report.

Figure 15 and 16

The final piece of information needed by SIMPLEV concerning the APU is the amount of fuel carried on board the vehicle. Enter the amount of fuel desired (in liters). The weight of this fuel will be added to the vehicle weight. The fuel consumed will be subtracted from the vehicle weight as it is used by the engine.

Auxiliary Loads. Auxiliary loads are those which are not used to propel the vehicle, such as headlights and loads not included in the efficiency data files, and represent constant electrical power loads connected directly to the traction battery terminals. Enter a value (in watts) at the prompt, if desired.

At this point, all of the necessary data describing the vehicle, powertrain, battery, and APU has been entered; however, before the simulation will begin, several other inputs are required.

Change Vehicle Parameters Menu. After all the required battery information is entered, the user is given the opportunity to change some of the vehicle parameters as shown in Figure 17. This menu displays the vehicle parameters which were read from the data files. If the gross vehicle weight is exceeded, a cautionary message is also displayed. The user may change any of the displayed parameters he wishes by entering the number or letter associated with the parameter. After entering the number, the user is prompted to enter a new value for this parameter. After a new value is entered, the menu is re-displayed with the new value. This process may be repeated as many times as necessary. If no further changes are desired, enter "0" (<zero>).

Saving Calculated Results. SIMPLEV performs a large number of calculations at each time step while running. The results of most of these calculations which may be of interest for analyses may be written to ASCII data files. Because of the large amount of data, these files can become very large, SIMPLEV provides for some screening so that only data of interest is saved.

In order to save the results to a file, enter "Y" at the appropriate prompt. If this is not desired, enter "N". After entering "Y", enter the name of the file to which you wish this data to be written. You may specify any valid drive/path along with the file name. Now the user may

Figure 17

select any (or all) parameters listed (shown in Figure 18) by entering the letter associated with the parameter he wishes to save. Note that in this menu, upper and lower case letters are significant. Saved parameters will disappear from the list and appear at the bottom of the screen. If you wish to delete a chosen parameter from the "chosen" list, merely re-enter the associated letter. In effect, entering letters associated with the parameters toggles them into and out of the "save" list. When all choices are made, enter "Z" and the user will be prompted for a time and cycle "window" in which to save data. Entering <Enter> to these prompts will save the chosen parameters at all points.

Screen Display Menu. A feature of SIMPLEV is that the user may view certain calculated data in graphical or numerical form while the program is running. One of the three forms of the results available while the program is running are initially chosen from the menu in Figure 19. Figures 20 and 21, and 22 show representative examples of the displays corresponding with menu selections "1", "2", and "3" respectively. Selection "1" shows battery power, battery voltage and battery current versus time. Selection "2" shows vehicle component efficiencies, motor power and vehicle speed versus time. If selection "3" is chosen, no graphs are displayed, however, many more parameters may be viewed. The user may switch between these display options by pressing function keys <F2>, <F3>, or <F4> corresponding to selections "1", "2", and "3" of this menu. After choosing a screen display option, the user may choose to print the graphical displays to an attached parallel printer by entering a "Y" at the prompt. Enter "N" if this is not desired. The user may select interactively which screens are to be printed by pushing the <F7> key while SIMPLEV is running. An indicator appears at the bottom left corner of each screen (either a "Y" or a "N" to indicate the current option to this prompt. Another way of printing the screen graphics display is to use the <Print Screen> key on the PC keyboard. Note: the DOS GRAPHICS command must usually be executed prior to running SIMPLEV if you choose to print the graphs.

Battery Display--This display (see Figure 20) provides information to the user concerning the calculated battery behavior at each time step of the chosen driving cycle. Beside each parameter plotted, the calculated value at each time step is also displayed. In addition to the vehicle, battery, and driving cycle identifiers at the top of the screen (i.e. vehicle and battery), other selected results are displayed numerically and updated at each time step.

Figure 18 and 19

Figure 20

Figure 21

Figure 22

Vehicle Speed and Component Efficiency Display--This display (see Figure 21) provides information to the user concerning the vehicle and component behavior at each time step of the chosen driving cycle. Beside each parameter plotted, the calculated value at each time step is also displayed. In addition to some identifying information at the top of the screen (i.e. vehicle and battery), calculated data is displayed numerically and updated at each time step.

Numerical Display--As shown in Figure 22, option "3" (or <F4>) provides most of the important parameters a user may wish to see. These values are updated at each time step of the program execution. A total of 41 parameters are displayed (21 if an APU is not selected).

Output Devices. One of 6 output devices may be selected by the user or no output at all (i.e. NUL) by selecting the number corresponding to the desired device (see Figure 23). The six output devices are LPT1, LPT2, COM1, CON (screen), AUX, and a user named DOS ASCII file. Graphs plotted on the screen may only be printed to one of the parallel port devices.

Calculated Vehicle Coastdown Curves. After selecting the screen display and device output options, SIMPLEV provides the user the opportunity of calculating, displaying, printing and saving the vehicle coastdown calculations for the previously chosen vehicle parameters and road conditions (grade and wind speed and direction). This option is shown in Figure 24. First the user is given a choice of whether or not he would like to perform this function. Enter "Y" for "yes" or "N" for "no" after this prompt. If the response "N" is chosen, SIMPLEV immediately begins calculating the vehicle and component performance for the selected driving cycle and road conditions. If the user responds with a "Y", additional information must be entered before the coastdown will begin.

Coastdown Display Menu. Figure 24 shows the coastdown display menu. Select "1", "2" or "3". Figures 25 through 27 show the resultant displays of these selections. After selecting a graphical display, the user is asked whether or not he would like to have this graph printed. Enter either "Y" or "N" in response, as appropriate.

Figure 23 and 24

Figure 25

Figure 26

Figure 27

Coastdown Options. After responding to the above prompt, the series of questions shown in Figure 24 is displayed and must be answered. First the user is asked for the time step or increment to compute the coastdown information. A value greater than 0 for this parameter should be entered. One second or less usually gives adequate resolution. Next the user is asked about writing the calculated coastdown data to a file. If answered "Y", the file name and time increment for saving data is prompted for before beginning the coastdown calculations. As a reminder, the file name entered as well as the data time increment is indicated on Page 2 of the output (see Figure 29). If the response is "N", the coastdown calculations begin immediately.

At the conclusion of the coastdown simulation, the user is given the opportunity to rerun the coastdown. The coastdown may be rerun with the same or a different graphic display. If no more coastdown runs are desired, answer "N" to this question and SIMPLEV then begins calculating the vehicle and component performance for the selected driving cycle and road conditions.

SIMPLEV Output

In addition to the screen graphics (which may be sent to a printer) and the ASCII file(s) of selected calculated results, SIMPLEV provides three pages of output (Figures 28 through 30). The system date and time that each SIMPLEV run is started is located at the top of each page along with the page number. With this information the user can distinguish between simulation runs. The specific information contained on these output pages is described below.

Simulation Inputs. Page 1 of the output contains the user furnished inputs to the simulation (sample shown in Figure 28). These data were obtained either from the component data files or were input interactively during the input session.

Vehicle Characteristics--The first section of information under "VEHICLE CHARACTERISTICS BASED UPON ..." gives the vehicle parameters used during the particular program run. As a reminder, when the vehicle data has been changed from the data contained in the ".VEH" data file, the header reads "MODIFIED VEHICLE CHARACTERISTICS BASED UPON ...". This information is given in both English and SI units.

Figure 28

Figure 29

Figure 30

Driveline Component Information--This section gives information of the driveline components used for each program run.

Controller/inverter--The name or origin of the component is given (read from the ".INV" data file, the name of the data file used, scaling factors used (if any) and the minimum voltage and maximum current limits of this component.

Motor--The name or origin of the motor used (read from the ".MOT" data file), the name of the data file selected, and scaling factors (if any) are given. In addition to this information, reference to the peak motor torque and power versus speed (rpm) is given if any scaling factors were employed. These modified motor characteristics appear on page 3 of the output.

Transmission--The name or origin of the transmission/transaxle selected (read from the ".TX" data file), the name of the data file selected, scaling factors (if any), gear ratios, and the vehicle speed at which a gear change occurs is given.

Battery Information--Information for the selected battery includes the result of any battery scaling chosen during the input session, the number of battery modules, the selected initial starting condition of the battery (ampere-hours removed at the specified rate and DOD), average battery power during the pre-discharge, and the battery efficiency during the pre-discharge, if applicable.

Auxiliary Power Unit--The auxiliary power unit consists of three separate components; a generator, an engine, and a catalytic converter. Information for these components are read from the ".GEN", ".ENG", and ".CAT" input files chosen during the input session. The following information on these components contained in the output is as follows:

Generator--The name given to the generator and the file name from which the generator information (efficiency versus normalized power and fuel constants) along with the maximum and minimum generator output power is given.

Engine--The name given to the engine and the file name from which the engine information (efficiency versus normalized power and emissions) along with the maximum engine output power is shown.

Catalytic converter--The name given to the catalytic converter and the file name from which the catalytic converter information (conversion efficiency and heat-up constants) is shown. If the catalytic converter is assumed to be pre-heated (option chosen during the input session), a notation to this effect is made.

Operation strategy--If the automatic mode of operation for the APU was chosen during the input session, this is noted along with the DOD of the battery in which the APU is turned "on" or "off". If the manual "on" and "off" mode (<F5> key entry method) is used, this is noted instead. One of the two modes chosen for determining the APU power is indicated. If the average power option is chosen, the time period chosen for averaging the power is shown. If the constant output power scheme is used, this power when the APU os "on" is noted.

Other Information--Other useful information on page 1 includes the name (and directory/path) of any data files which were chosen to be written as SIMPLEV executes. A notation giving the reason for the simulation termination also appears on page 1 if no graphical outputs were requested. If graphical outputs were requested, then this notation appears after the last graph.

Screen Output. As SIMPLEV executes, the computer monitor displays the results according to the format chosen in the Coastdown Graphical Display Menu (if the vehicle coastdown option is chosen) and the Screen Display Menu. If option "3" is chosen in the Screen Display Menu, calculated parameters at each time step are displayed. In the lower left corner of the display, a notation giving the execution speed ("1" through "4", with "4" being the slowest) and whether or not the current graph will be printed (indicated by a "Y" or "N" for yes or no respectively). This indicator is only present if the <F7> key is pressed. These indicators are erased prior to the display being printed. The displays are printed between pages 1 and 2 of the printed output. Figures 20 and 21 are representative of these graphs

Indicators representing limiting conditions on a driving cycle may occasionally flash. In general, these indicate that the simulated vehicle cannot meet the performance requested of the particular driving cycle. When "VOLTS" flashes, the battery voltage is clamped at the minimum controller/inverter voltage at that point in the cycle. When "AMPS" flashes, that the inverter/controller is operating at its maximum current limit. When "MOTOR" flashes, the motor is operating at the maximum torque. When "TC/ABS" (traction control/antilock braking system) flashes, the vehicle speed at that point in the cycle was limited by the tire/road traction. In all of these cases, the vehicle speed has been augmented for the indicated reason.

When "MOTOR" blinks during deceleration, the vehicle speed has not been augmented, but the instantaneous energy returned to the battery has been limited by the motor. In this case it is assumed that the remainder of the energy was absorbed by the vehicle brakes.

Any graphical outputs requested are only printed if a parallel printer port was designated for the output. Sample outputs using the IDSEP vehicle and component data and the 170 Ah NIF-170 nickel-iron battery data supplied with the simulation code are shown in Figures 20 and 21.

Simulation Results. A sample of the printed output (pages 2 and 3) is shown in Figure 29 and Figure 30, respectively. The date and time of the initial execution of SIMPLEV appears at the top of each page. This information is useful should the three pages of output from a particular run become separated.

Calculated Coastdown Times--If the vehicle coastdown option is chosen from the menus, the estimated coastdown times for three different speed ranges are printed: 60 - 10 mph, 20 - 10 mph, and 55 - 45 mph. The calculated times for these speed ranges are linearly interpolated from the calculated data. A notation as to the resolution accuracy of these values is made based upon the time interval supplied by the user.

Steady State Road Loads--The calculated constant speed road loads are given for various road speeds at the chosen road conditions (grade, wind speed and direction, and air density).

Detailed Results--The remainder of page 2 of the output contains a detailed summary of the results of the simulation run up to the point that this output was activated (<Ctrl-i>, <F10>, or automatic program termination). The calculated results are given in English and Standard International (SI) units where a clear convention has not been established. An explanation as to the meaning or significance of the calculated quantities appearing on the remainder of page 2 is given below. Note that not all of the parameters described will appear for all simulations. Only those parameters which have meaning will be given (for instance, parameters having to do with an APU will not be given if a vehicle with an APU was not simulated).

Cycle and Road Conditions --The driving cycle simulated along with a notation as to the driving cycle speed versus time data file is given as well as the time increment of the speeds used. In general, the time increment for relatively complicated driving cycles supplied with SIMPLEV Version 2.0 (e.g. FUDS or SAE J227a cycles) is 1 s while less complicated driving events such as constant speeds have a longer time increment. The road conditions

(air density, vehicle heading, wind speed and direction, and road grade) are listed. If the simulation is under road conditions other than still air, the equation and the coefficients used for correcting the vehicle aerodynamic drag coefficient is given.

Maximum Battery Power --The point in the driving cycle at which the maximum discharge battery power occurred is captured by SIMPLEV. The maximum battery power (kW) and the voltage and current at the time of this occurrence is listed.

Average Battery Current And Power --The average battery current and power for charge, discharge and net is given for the driving portion of the simulation.

Ampere-hours discharged and charged --This value represents the ampere hours out of and into the battery from the beginning of the simulation until the output is activated, and does not include any pre-discharge quantities.

Effective Battery Capacity --The effective battery capacity (in ampere-hours) represents the estimated battery capacity for the simulation. The effective battery capacity includes the effects of any pre-discharge.

Net Battery Energy --This quantity is net energy which passes through the battery terminals (i.e. discharge energy minus charge energy).

Gross Battery Energy --This quantity is the sum of all discharge energy passed through the battery terminals.

Energy Supplied By APU and Regenerative Braking --These values represent the total energy either supplied by the APU or returned to the battery from regenerative braking, respectively.

Electrical Energy Supplied to Wheels --This value represents the electrical energy which was used for motive power.

Percent of Energy Supplied by Regen --This quantity (expressed as a percentage) is the fraction of energy supplied to the battery from regenerative braking compared to the total energy discharged at the battery terminals.

Component efficiencies --The average component efficiencies for the simulation run are calculated and printed. Separate efficiencies for the two modes of component operation are given: charge or regenerative braking and discharge or driving. For the battery, inefficiencies represent deviations from an ideal battery (i.e. no resistance losses).

The remaining component efficiencies are calculated from the energy into a component divided by the energy out of a component. The powertrain efficiency is the combined average efficiencies of the controller/inverter, motor and transaxle (i.e. energy into the inverter/controller divided into the energy out of the transmission).

APU energy economy --This quantity represents the total energy out of the APU divided by the total distance up to the point that the summary is given.

Net Traction Energy Economy --This quantity represents the net energy supplied to the powertrain divided by the distance driven up to the point that the summary is given.

Net Battery Energy Economy --This quantity represents the net energy out of the battery divided by the distance up to the point that the summary is given.

Gross Battery Energy Economy --This quantity represents the total energy withdrawn from the battery divided by the distance up to the point that the summary is given.

Maximum Battery Power Density --The maximum battery power density encountered is calculated from the captured maximum battery power divided by the battery weight. Generally, ancillary battery equipment (charger, heaters, etc.) is not included in the battery weight unless added during the input session (Figure 17) by the user.

Average Speed --The average speed is calculated from the distance traveled during the simulation divided by the driving time. For driving cycles which specify "vehicle off" rest periods (e. g. FUDS and SFUDS), these rest periods are not included in this calculation.

Total Distance Traveled --The distance traveled during the simulation run is calculated by integration of the calculated vehicle speed at each time increment of the cycle simulated.

Test Time--The real time of the simulation is calculated. For driving cycles which specify "vehicle off" rest periods (e. g. FUDS and SFUDS), these rest periods are not included in the calculated test time.

Number of Cycles Completed --The number of whole cycles completed (or number of screens for non-cyclic speed versus time events) at which this page is activated is given.

DOD at Termination --The depth-of-discharge (DOD) of the traction battery when the simulation was terminated (or summary activated) is calculated and shown.

Battery Voltage and Current at Termination --The traction battery voltage and current at the point of termination (or activation of this summary) of the simulation run is shown.

FUDS Cycle Information --This information appears only for FUDS cycle simulations where the "flag point" as described in the draft SAE J227 Electric Vehicle Test Procedure (time, cycle number and distance) is encountered.

Emissions--If an APU was simulated, a summary of the gaseous emissions is given in total grams and grams per unit of total distance traveled (in miles and kilometers). Additionally, the amount of fuel consumed, and the fuel economy is given up to the point that the summary was activated. If an APU simulation was chosen, and has not yet been turned on, a notation to this effect is given instead.

Average Component Power Losses--The average component losses for the test run is calculated for each driveline component and given on Page 3 (Figure 30). The losses for each component generally represent heat generated. These losses are given for both the driving and regeneration modes of component operation and totaled.

Steady State Powertrain Efficiencies--The driveline efficiencies under constant speed conditions and the input road conditions for the simulation run are calculated and displayed.

Simulation Diagnostics--This section of the printed output provides an indication of the quality of the simulation. SIMPLEV cannot invent component behavior. However, in order to avoid terminating a simulation in the case of missing or incomplete component data, the efficiencies in the component data files may be extrapolated beyond the values contained in the input files. In this case, SIMPLEV continues to execute and tally the number of times that the information in the data files was extrapolated. In general, a low number (compared to the number of speed points in the simulation) indicates a good quality run, while a high number may indicate that the component operated excessively outside its defined regime, and the simulation results may be suspect.

Troubleshooting

SIMPLEV contains many built in checks on input data validity as well as provisions for extrapolating data beyond the information contained in the input files (explained above). In general, these checks and extrapolations allow SIMPLEV to run without encountering computation errors (such as division by zero). Therefore, problems during the program execution can most likely be attributed to some other cause.

SIMPLEV has been used extensively on many IBM DOS computers, ranging from IBM PCs, XTs, and PS/2s and DOS versions through 5.0 without problems. Some Terminate and Stay Resident (TSR) software programs and some network programs conflict with SIMPLEV, producing random and unpredictable execution problems. If an unexplained problem occurs during the program execution, it is suggested that these programs be unloaded prior to executing SIMPLEV.

If printed graphs do not appear as on the computer monitor, the user should check to verify that the proper GRAPHICS command (depending upon the user's particular DOS version) has been executed.

SIMPLEV Version 2.0 is written in 12 interconnected modules. These modules are listed below with a brief description of the function of each. Because the compiler generally identifies the module which could not be executed, a basic knowledge of the module functions can help in identifying input anomalies.

SIMPLEV - This module contains the algorithms which perform the mathematical calculations of the simulation. In addition, this module controls the simulation output both to the computer monitor and

output devices, and calls the other modules as necessary. Most serious errors which cause failure in execution occur in this module, and are generally due to faulty input parameters.

LOADVEH - This module reads the selected data file containing the vehicle parameters. The specific information read by this module and the proper file format is discussed under the heading Vehicle definition in the following section of this report.

LOADMOT - This module reads the selected motor and inverter/controller data file containing the efficiency matrices and other information. Scaling of motors and inverters/controllers is also performed in this module. The specific information read by this module and the proper file format is discussed under the headings Motors and Inverters/Controllers in the following section of this report.

LOADTX - This module reads the selected transmission data file containing the efficiency matrices, gear ratios and other information. Scaling of conventional transmissions as well as defining continuously variable transmissions are also performed in this module. The specific information read by this module and the proper file format is discussed under the heading Transmissions in the following section of this report.

LOADBTY - This module reads the selected battery data file containing open circuit voltage and battery resistance descriptions. Scaling of the battery is also performed in this module. The specific information read by this module and the proper file format is discussed under the heading Battery Files in the following section of this report.

LOADCYC - This module reads the selected driving cycle data file containing the speed versus time description of the cycle. Additionally, weather and road conditions are input to SIMPLEV through this module. The specific information read by this module and the proper file format is discussed under the heading Driving Schedule Files in the following section of this report.

COASTDWN - This module performs a simulated vehicle coastdown with all its associated calculations and outputs to the computer monitor and ASCII files. Errors due to faulty input parameters may occur in this module, however, they are less common than in the SIMPLEV module.

RITEDATA - This module performs all of the writing data file operations.

USERF - This module is called to read file names from the disk and assign letters to them for selection. The USERF module is called from within LOADVEH, LOADMOT, LOADTX, LOADCYC, LOADBTY, and APUINP modules if necessary.

APUINP - This module performs all of the information input functions associated with the auxiliary power unit, such as reading selected information files and selecting APU operation options.

APUCALC - This module performs all of the calculations associated with the operation of an APU, including calculating the APU power output and APU emissions.

INTERP - This module performs all single linear interpolation functions (i.e. battery, motor, inverter, and APU components).

Compiler Error Messages

Error messages produced by the BASIC compiler generally identify the module in which the error occurred. The following compiler error messages likely to be generated is given below along with a description of the probable cause of the error.

Out of Memory. There is not enough computer memory available to run SIMPLEV. SIMPLEV requires approximately 280 kB of computer RAM to run. The user should free some memory by unloading any memory resident programs, or run SIMPLEV on a PC with at least 280 kB of available memory.

Out of String Space. This is not a common error. It is caused by exceeding the maximum space available for string variables. Shorten the text comments and text identifiers in the component data files that were read previous to this error.

Device Timeout. Either SIMPLEV tried to use your printer or external disk drive and it was not turned on, or you do not have the specified device attached to the PC. Turn on or attach the appropriate device.

Device Fault. Either SIMPLEV tried to use a printer or external disk drive that was specified and it was not turned on, or your requested printed graphs and do not have a parallel printer attached to the PC.

Turn on or attach the appropriate device. Other causes of this error can be associated with device failure on trying to read unformatted or write protected disks.

Printer Out of Paper. The printer attached to the PC parallel communications port (usually LPT1) is out of paper. The user should put paper in the printer.

File not Found. Either SIMPLEV could not find the component data file as specified or the diskette in which data was initially output to was taken out of the diskette drive. A common cause of this error results from the data files selected from the menus are not in the same drive/directory as SIMPLEV.EXE.

Disk Full. SIMPLEV tried to write data to a full disk. Files created by SIMPLEV containing data can become very large.

Permission Denied. SIMPLEV tried to write data to a write-protected file or diskette. Removing the write-protection as appropriate will eliminate this error.

Drive Door Open. The diskette drive door specified for either input or output files is open.

Path Not Found. SIMPLEV was unable to find the path specified for output files. Usually, the intended path does not exist or it was misspelled.